Supplementary Information for

A New Pathway for Cross-Scale Energy Transfer during Solar Wind–Magnetosphere Interaction

Z. Z. Chen[1,2✉], H. S. Fu[1,2✉], J. B. Cao[1,2], J. Yu[3], T. Y. Wang[4], O. Le Contel[5], C. T. Russell[6], C. J. Pollock[7], P. A. Lindqvist[8], R. E. Ergun[9], J. P. McFadden[10], W. D. Fu[1,2], Z. Y. Xu[1,2], Z. Z. Guo[11], Y. Yu[1,2], J. Wang[3], J. Cui[3], J. L. Burch[12]

[1]School of Space and Earth Sciences, Beihang University, Beijing, China

[2]Key Laboratory of Space Environment Monitoring and Information Processing, Ministry of Industry and Information Technology, Beijing, China

[3]Planetary Environmental and Astrobiological Research Laboratory (PEARL), School of Atmospheric Sciences, Sun Yat-sen University, Zhuhai, China

[4]School of Earth Sciences, Yunnan University, Yunnan, China

[5]Laboratoire de Physique des Plasmas, CNRS-Ecole Polytechnique, UPMC, Palaiseau, France

[6]Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, CA, USA

[7]Denali Scientific, San Antonio, TX, USA

[8]KTH Royal Institute of Technology, Stockholm, Sweden

[9]Department of Astrophysical and Planetary Sciences, University of Colorado Boulder, CO, USA

[10]Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA, USA

[11]Faculty of Information Engineering and Automation, Kunming University of Science and Technology, Kunming, China

[12]Southwest Research Institute, San Antonio, TX, USA

✉Correspondence to Z. Z. Chen at chenzzh@buaa.edu.cn

and H. S. Fu at hsfu@buaa.edu.cn

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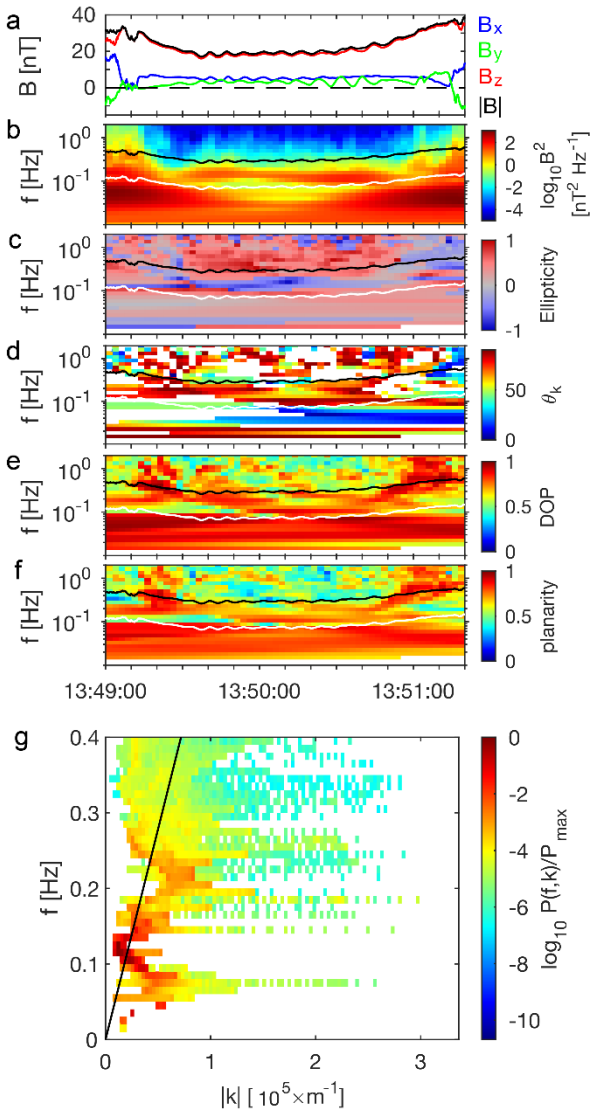
Supplementary Fig. 1.



Supplementary Fig. 1. Properties and dispersion relation of ULF waves. The data was detected by MMS. **a-f**, Wave polarization analysis showing magnetic field (**a**), power spectral density of the magnetic field (**b**), ellipticity (**c**), wave normal angle (**d**), degree of polarization (**e**) and planarity (**f**). The black and white curves in panels **b-f** represent proton gyrofrequency (f_{cp}) and ionized helium (He^+) gyrofrequency (f_{cHe}), respectively. **g**, Observed dispersion relation showing wave power versus frequency and wave number. The black line in panel **g** denote the average wave speed v~350 km/s. The wave dispersion relation can be resolved using the cross power spectral between the magnetic or electric fields measured by four spacecraft. The phase difference $\Delta\psi$ between the detected waves by any spacecraft pair is determined by $\Delta\psi = \arctan\left(\frac{Im\left(\langle W_\alpha(f,t)W_\beta^*(f,t)\rangle\right)}{Re\left(\langle W_\alpha(f,t)W_\beta^*(f,t)\rangle\right)}\right)$, where W_α and W_β are the wavelet transforms of detected fields by any spacecraft pair. The corresponding wave vector for a specific frequency can be then determined by incorporating the inter-spacecraft separation.